Duke Engineering & Services

Surfactant-Enhanced Aquifer Remediation (SEAR)

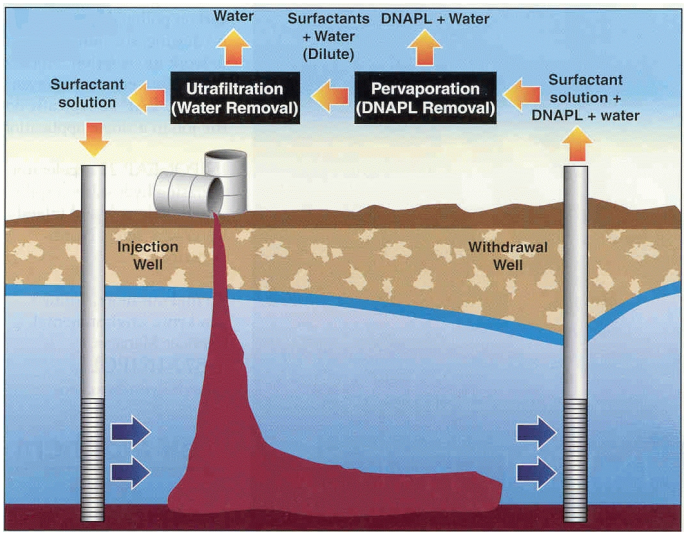
Technology Need:

Conventional pump and treat systems have not been successful in remediation of aquifers that contain dense, non-aqueous phase liquids (DNAPLs). Such treatment relies on diffusion and advection of contaminants as the primary removal mechanisms. These mechanisms are relatively passive, resulting in long clean-up durations and indefinite end points. DNAPLs are more dense than water, so they sink readily into the aquifer system when released. DNAPLs also have a very low solubility in water, so they tend to exist as pockets that dissolve slowly over time. Further complicating remediation, are the low cleanup standards to which these contaminants must be reduced. A technology is needed which can provide faster, more cost-effective removal of DNAPLs from the subsurface.

Technology Description:

Surfactant-Enhanced Aquifer Remediation (SEAR) is an alternative process to standard pump-and-treat methods. The SEAR process employs various surfactants to promote accelerated removal of DNAPL source areas. With SEAR, DNAPL solubility is considerably enhanced, allowing significantly quicker; therefore, less expensive remediation. SEAR involves the injection of micellar surfactant solutions, to solubilize and mobilize DNAPL constituents. The surfactant and contaminants are subsequently extracted through strategically-placed pumping wells. Above ground processes are typically utilized to treat the contaminated groundwater and recycle the surfactant if necessary. Various design approaches may be taken to SEAR, depending upon the hydrogeological conditions and the physical-chemical properties of the DNAPL.

The solubilization mechanism, which is at the heart of the SEAR process, is the formation in groundwater of micelles, (i.e., colloidal clusters of nonionic surfactants)



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in which the molecules of the DNAPL are dissolved and then transported by the groundwater. In the field, SEAR works similarly to pump-and-treat operations except that dilute surfactant solutions are injected into the contaminated aquifer and withdrawn together with the solubilized DNAPLs.

At certain characteristic concentrations, surfactants exhibit marked changes in several physical and chemical properties, (e.g., electrical conductivity, interfacial tension, and detergency). At this concentration, the polar and nonpolar groups become oriented such that they form colloidal clusters of molecules in solution. The concentration of the surfactant at which these phenomena occur is known as the critical micelle concentration.

The clusters are characterized by the interfacing of the hydrophilic groups with the water molecules on the outside of the cluster, while the hydrophobic groups are arranged pointing towards the interior of the cluster. In the removal mechanism, the hydrophobic DNAPL molecules are solubilized inside the micellar assemblage of the surfactant; thus, solubilized within

the groundwater for transport.

Benefits:

▸Removes DNAPL source.

▸Significantly reduces the number of pore volumes of groundwater that must be withdrawn from the aquifer.

▸Cost and time savings compared to current methods.

▸99% removal of DNAPL at 10% of cost of pump-and-treat.

Status and Accomplishments:

This project was concluded in May 1997 and the SEAR process is commercially available from Duke Engineering and Environmental Services (DE&S). The technology has been demonstrated and deployed at numerous DOE, Department of Defense (DOD) and commercial sites.

SEAR has been demonstrated at the following sites (the year and contaminant are included in parentheses):
▸Portsmouth Gaseous Diffusion Plant (Trichloroethylene (TCE)-DNAPL, 1997);
▸Marine Corp Camp Lejeune (Perchloroethylene (PCE)-DNAPL, 1998);
▸Pearl Harbor Naval Base (Navy Special Fuel Oil, light-NAPL (LNAPL), 1999); and
▸ICOR, Bloomington, IL (Coal Tar, 2001).

The most extensive application of SEAR has been at Hill Air Force Base (AFB) in Layton, Utah. SEAR has been deployed at Hill AFB three times since 1996 and another surfactant flood is planned for 2001. Most of the deployments have been at Operable Unit 2 (OU2) for DNAPL remediation, but the first deployment was at Operable Unit 1 (OU1) for remediation of LNAPL.

Operable Unit 2 at Hill AFB was used to dispose chlorinated organic solvents primarily trichloroethene (TCE), in unlined disposal trenches underlain by an alluvial aquifer. In the first OU-2 deployment, the SEAR technology demonstrated recovery of 98.5% of DNAPL (510 of 516 gallons).

During the three surfactant floods at Hill AFB, the Partitioning Interwell Tracer Test (PITT) was utilized for subsurface characterization. PITT (OST ID 2963) is a DNAPL characterization technique marketed by DE&S that is capable of determining the spatial distribution and volume of residual DNAPL in the subsurface. The PITT involves the injection of a suite of tracers into one or more wells and subsequent extraction of the tracers from other wells in a field.

Duke Engineering & Services has since been sold to Framatome ANP DE&S .

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Online Resources:

Office of Science and Technology, Technology Management System (TMS), Tech ID # 297
http://ost.em.doe.gov/tms

The National Energy Technology Laboratory Internet address is http://www.netl.doe.gov

For additional information, please visit the Framatome ANP DE&S Internet website at http://www.framatomeanp-des.com/

The SEAR Technology Alliance Internet address is http://www.dnapl.com/publications.html